Table 8a. Densities of Marbled Murrelets along the outer coast of Washington between Fuca Pillar and Point of Arches in 1995 and 1996.

Distance (m) of transect from shore	1995				1996			
	Summer		Winter[1]		Summer		Winter[2]	
	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)
400	3.64 ± 0.10 (2, 4.10)	2.20 ± 0.10 (2, 6.40)	--	--	--	--	--	--
700	--	--	--	--	--	--	--	--
1200	0 (2, --)	0 (2, --)	--	--	--	--	--	--

[1] Winter of 1995-1996
[2] Winter of 1996-1997

Table 8b. Densities of Marbled Murrelets along the outer coast of Washington between Fuca Pillar and Point of Arches in 1997 and 1998.

Distance (m) of transect from shore	1997				1998			
	Summer		Winter[1]		Summer		Winter[2]	
	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)
400	0.96 ± 0.42 (5, 96.8)	2.57 ± 0.82 (5, 71.0)	3.93 (1, --)	--	3.33 ± 0.95 (6, 70.2)	0 (1, --)	--	--
700	0.67 ± 0.23 (5, 78.6)	0.39 ± 0.05 (3, 21.9)	6.30 ± 1.12 (5, 39.8)	6.18 ± 0.73 (4, 23.8)	1.20 ± 0.01 (2, 1.20)	0.92 ± 0.57 (3, 107)	--	--
1200	0.71 ± 0.29 (4, 80.8)	0.40 ± 0.35 (5, 195)	4.76 ± 0.23 (4, 9.70)	4.94 ± 1.16 (6, 57.5)	0.52 ± 0.18 (2, 47.1)	0.38 ± 0.38 (3, 173)	--	--
Zig-Zag	1.16 ± 0.43 (6, 90.4)	0.44 ± 0.32 (3, 124)	--	--	0.65 ± 0.39 (4, 118)	--	--	--

[1] Winter of 1997-1998
[2] Winter of 1998-1999

Although these data may be used to address many issues including variation in murrelet density in relation to year, season, time of day, distance from shore, and geographic location, the immediate reason this research was funded was to complete two tasks: (1) to compare the mean, variance, and coefficient of variation in zig-zag transects to those of each parallel transect distance (e.g. 200m vs. 500m), and to recommend which type of transect (parallel or zig-zag) is best for long-term monitoring of murrelets.

Zig-zag transects have two advantages over parallel transects. First, as documented previously (Thompson 1997a, 1997b), murrelets tend to occur in higher densities in morning versus afternoon in summer (Tables 6 and 7, Figures 1 and 3); a similar but less pronounced pattern exists in winter (Tables 6 and 7, Figures 2 and 4). Thus, differences between parallel transects conducted at different distances from shore may be confounded by time-of-day effects unless they are conducted at the same time of day. This is not an issue with zig-zag transects because the temporal distribution of effort is the same across all distances from shore within the area surveyed. Second, it is well known that murrelet density decreases with perpendicular distance from shore (Thompson 1997a, 1997b); This is further documented here (Tables 6 and 7, Figures 1-5); however, the peak in this density is also known to vary among geographic locations, and, more importantly, over time within and between seasons and years within geographic areas (Tables 6 and 7, Figure 5). Thus, surveys conducted along a specific parallel transect may vary over time due to changes in the overall density distribution of murrelets in relation to distance from shore (e.g., a shift in the distance at which maximum density of muurelets occurs) rather than to actual changes in total murrelet abundance. Because zig-zag transects sample a much wider range of distances from shore, they are less likely to be affected by such changes in the density distribution of murrelets in relation to distance from shore. These advantages aside, comparison of coefficients of variation between zig-zag and parallel transects do not clearly indicate that one kind of transect (i.e. zig-zag vs. parallel) is superior for maximizing statistical power for detecting changes in population density. This issue is currently being discussed by the "Population Core Group," a group of four biologists (myself, Steve Beissinger [University of California at Berkeley], C.J. Ralph [U.S. Forest Service, Pacific Southwest Region], Marty Rafael [U.S. Forest Service, Pacific Northwest Region]) and two statisticians (Tim Max and Jim Baldwin) who are coordinated by the U.S. Fish and Wildlife Service; the charge of this group is to develop a protocol for surveying for murrelets at sea, the data from which will be suitable for monitoring population trends of murrelets at sea. Jim Baldwin and Steve Beissinger are currently using empirical data to run simulation models to evaluate the relative strengths and weaknesses of parallel versus zig-zag transects. We anticipate an answer from them this summer.

The second reason for conducting replicate sets of these various transects was to determine how many replicates of a given transect should be done, on average, in a given area (e.g. outer coast versus Strait of Juan de Fuca) and season (winter vs. summer) in order to achieve the statistical power required to detect a change in density of murrelets of a given magnitude over a specified time interval. As briefly explained above, the Population Core group has not yet decided how transects should be oriented (e.g. zig-zag versus parallel), at what distance from shore they should be placed, or how long they should be. Nor has any state or federal agency stated a specific percent change in murrelet populations that they want to be able to detect over a given number of years. As a result, I can not present a power analysis for a generally accepted sampling scheme, because no such consensus currently exists. Instead, I present a preliminary power analysis for the summer season for a subset of transect types and lengths that WDFW conducted between 1995 and 1998. As mentioned above, transects along the Strait of Juan de Fuca were conducted parallel to shore at 200, 500, 800, and 1200 meters, and in a zig-zag orientation between 100 and 1300 meters from shore. Statistical power increases as the coefficient of variation (CV) within each of the two or more samples being compared decreases. Thus, for the power analysis presented below, I chose the 500 m and 400 m parallel transects on the Strait of Juan de Fuca and outer coast, respectively, to compare to zig-zag transects conducted in the same location because these transects had lower CVs than other parallel transects (see Table 9 below). Using values from Tables 7 and 8 above, I calculated the grand mean murrelet density for each transect type and location, and the standard deviation of individual means (rather than the mean of the standard deviations of the individual means) included in the calculation of each grand mean; these values were as follows: 500m SJF: 3.59 ± 2.39, zig-zag SJF: 3.68 ± 3.10; 400m OC: 2.54 ± 1.05; zig-zag OC: 0.75 ± 0.37.

Table 9. Coefficients of variation of strip transects conducted along the western Strait of Juan de Fuca and the northern outer Washington coast in 1995-1998 (years and time of day combined)

	Season		
Transect Type	Summer mean (SD, n)	Winter mean (SD, n)	Location[1]
200m	101 (45.3, 6)	98.2 (47.1, 6)	SJF
500m	74.2 (43.5, 8)	69.1 (40.0, 6)	SJF
800m	111 (30.1, 8)	89.0 (19.8, 4)	SJF
1200m	141 (0, 3)	132 (9.5, 2)	SJF
Zig-Zag	89.0 (13.3, 6)	63.3 (12.2,4)	SJF
400m	49.7 (41.9, 5)	--	OC
700m	52.2 (49.0, 4)	31.8 (11.3, 2)	OC
1000m	124 (71.1, 4)	33.6 (33.8, 2)	OC
Zig-Zag	111 (18.1, 3)	--	OC

[1] SJF = western Strait of Juan de Fuca; OC = northern outer Washington coast.

Based on these data, I calculated the power of detecting changes in population density between two sampling periods (e.g. successive years) in 10% increments from 10% to 90% along the western Strait of Juan de Fuca and the northern outer Washington coast using 5, 10, 15 and 20 replicates during each survey period. Along the western Strait of Juan de Fuca, 500 meter transects parallel to shore have greater power for the same number of replicates than do zig-zag transects (Figs. 6-7); interestingly, however, the opposite is true for the northern outer Washington coast (Figs. 8-9). Based on this cursory analysis, neither type of transect appears to be consistently superior to the other. In addition, it is noteworthy, although not surprising, that the statistical power for detecting changes in murrelet density along the Strait of Juan de Fuca is relatively poor (about 50%) for detecting large changes (e.g. 50%) in murrelet density even if twenty transects are conducted in each of the two years (Figs. 6-7). In contrast, the power for detecting similar changes in murrelet density on the outer coast is much greater for the same number of transects (Figs. 8-9). This, of course, is a result of the coefficient of variation that I used in the power analysis was much lower for the outer coast (41.34% for 400 m; 49.33% for zig-zag) than for the Strait of Juan de Fuca (66.57% for 500 m; 84.24% for zig-zag). All else being equal, the coefficient of variation in density among transects decreases as a function of transect length; however the transects conducted along the Straits and on the outer coast were the essentially identical in length. Thus, the reason for lower coefficients of variation among transects along outer coast versus the Strait is unclear, but it is likely that the higher intra-seasonal (intermonthly) variation in murrelet density along the Strait versus the outer coast is at least partly responsible for lower coefficients of variation among transects along outer coast versus the Strait.

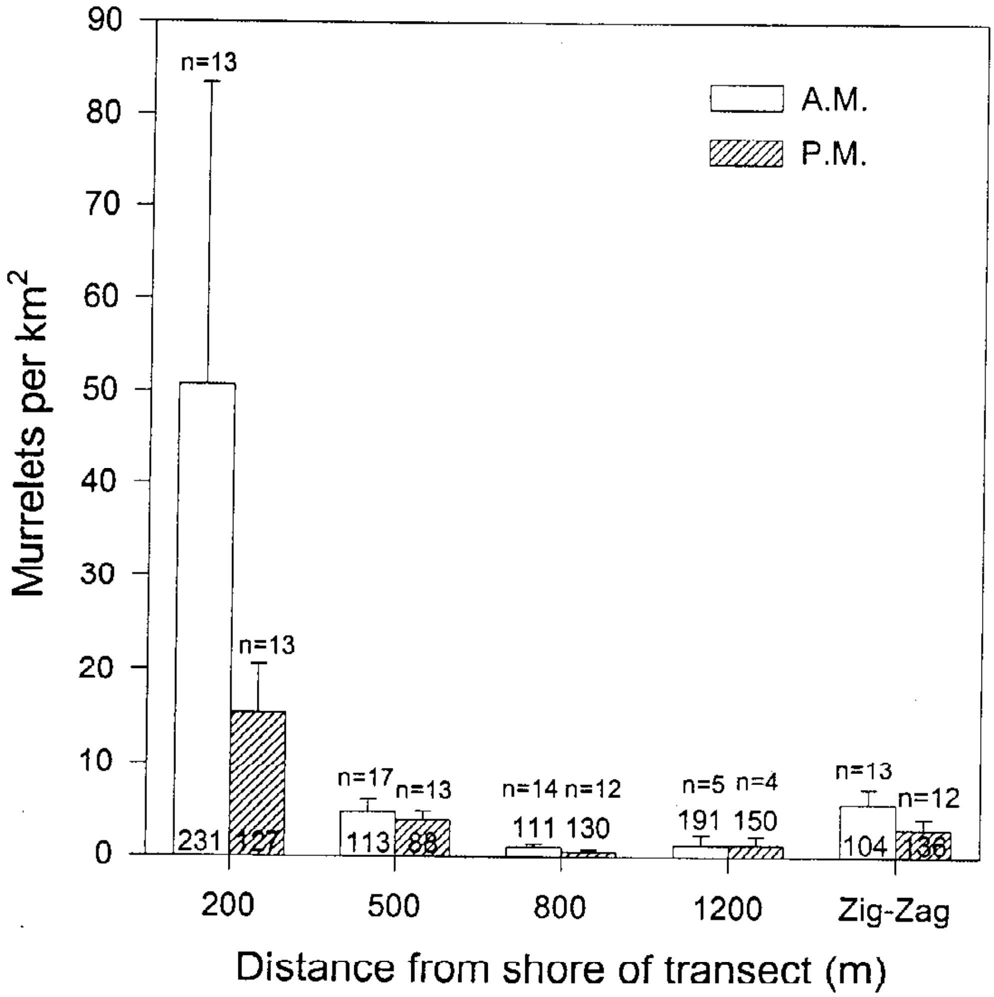

Figure 1. Density of Marbled Murrelets along the western Strait of Juan de Fuca in summer 1995 through summer of 1998 in relation to distance from shore and time of day. Numbers below sample sizes indicate coefficients of variation.

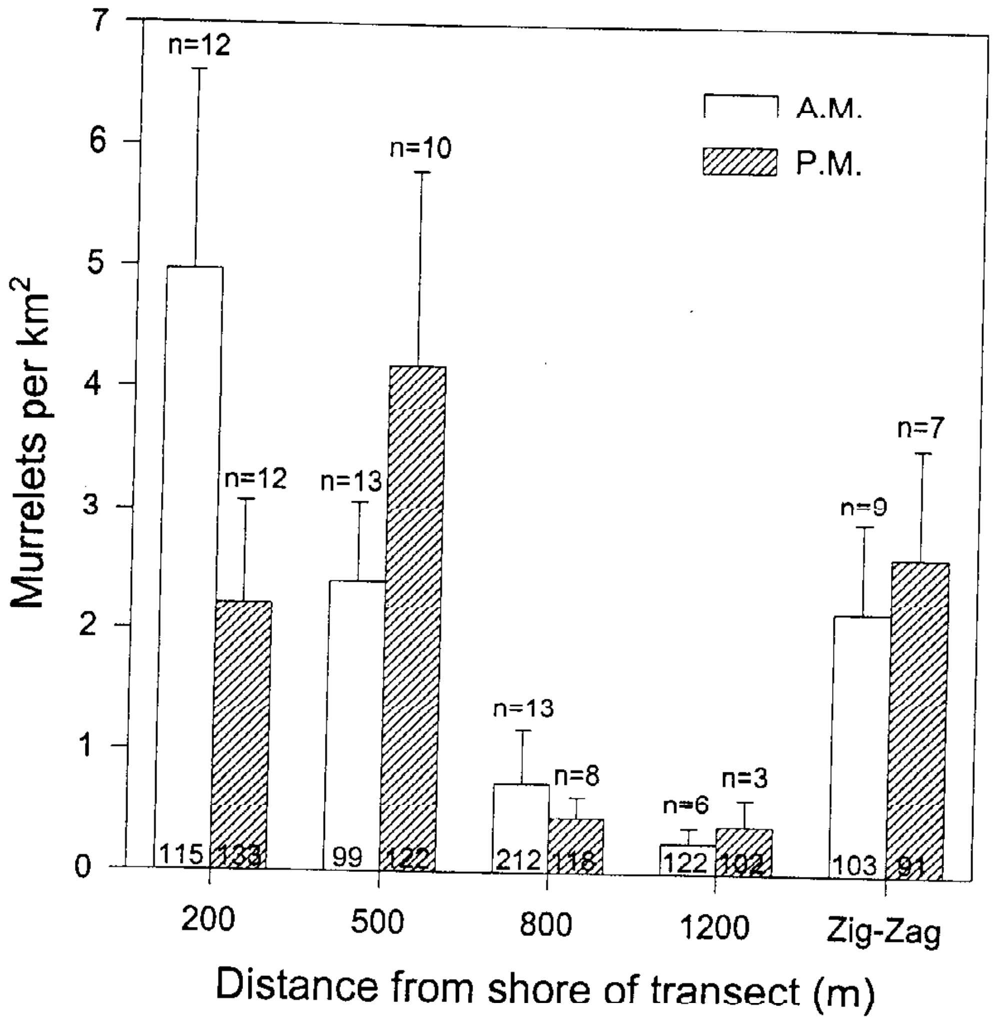

Figure 2. Density of Marbled Murrelets along the western Strait of Juan de Fuca in winter 1995 through winter of 1998 in relation to distance from shore and time of day. Numbers below sample sizes indicate coefficients of variation.

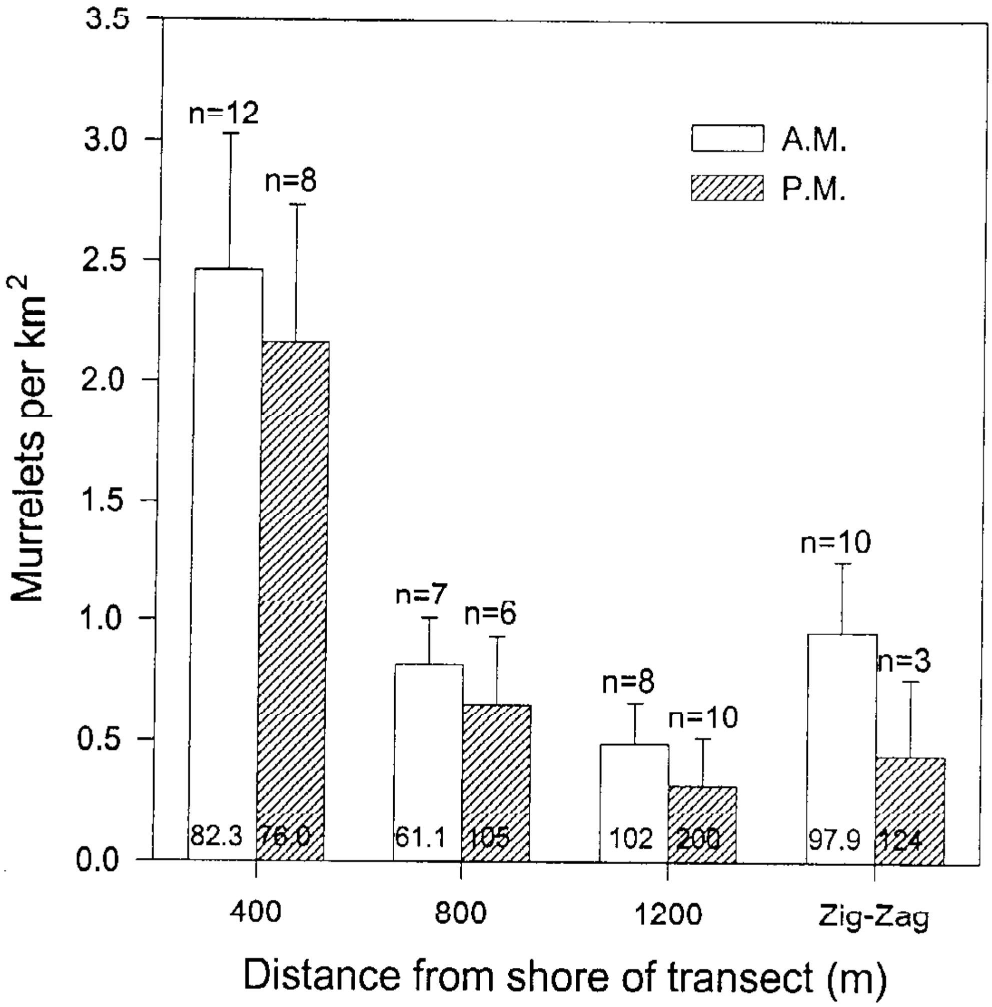

Figure 3. Density of Marbled Murrelets along the northern outer coast of Washington in summer 1995 through summer of 1998 in relation to distance from shore and time of day. Numbers below sample sizes indicate coefficients of variation.

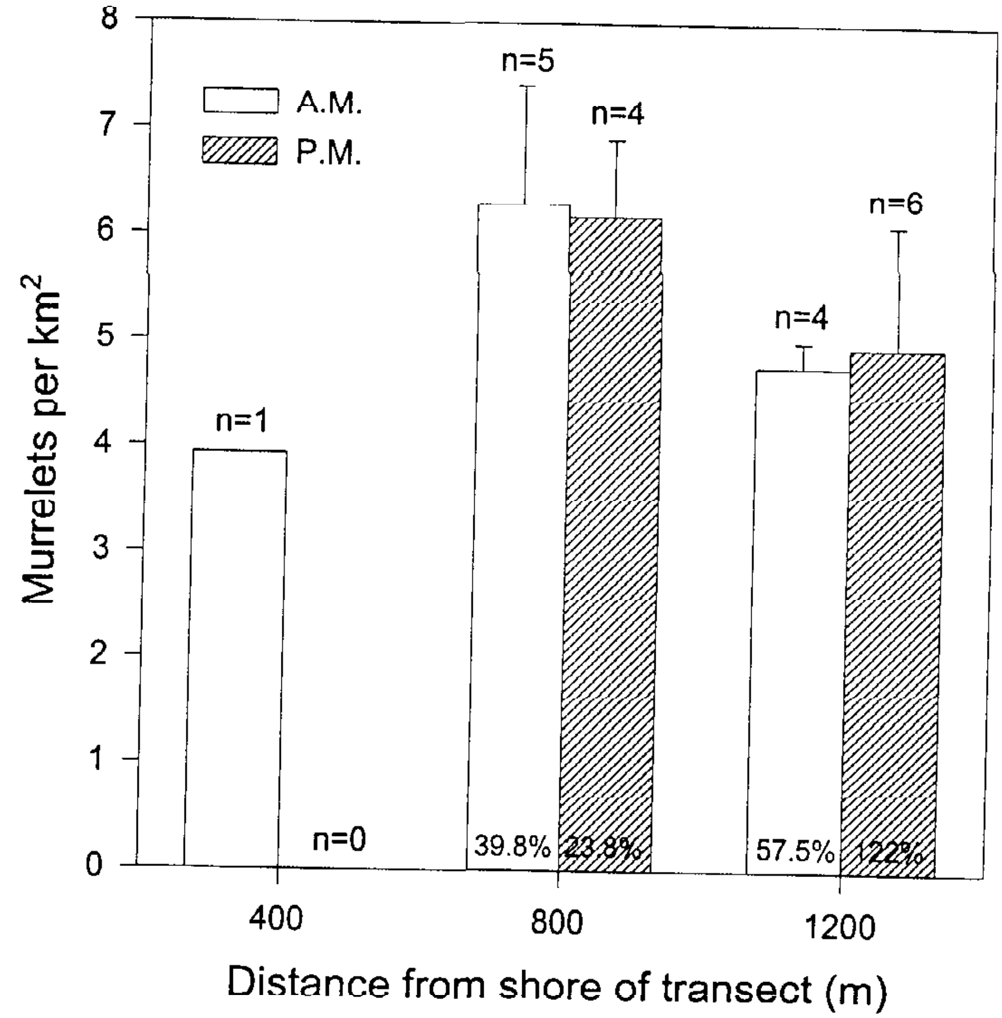

Figure 4. Density of Marbled Murrelets along the northern outer coast of Washington in winter 1995 through winter of 1998 in relation to distance from shore and time of day. Numbers below sample sizes indicate coefficients of variation.

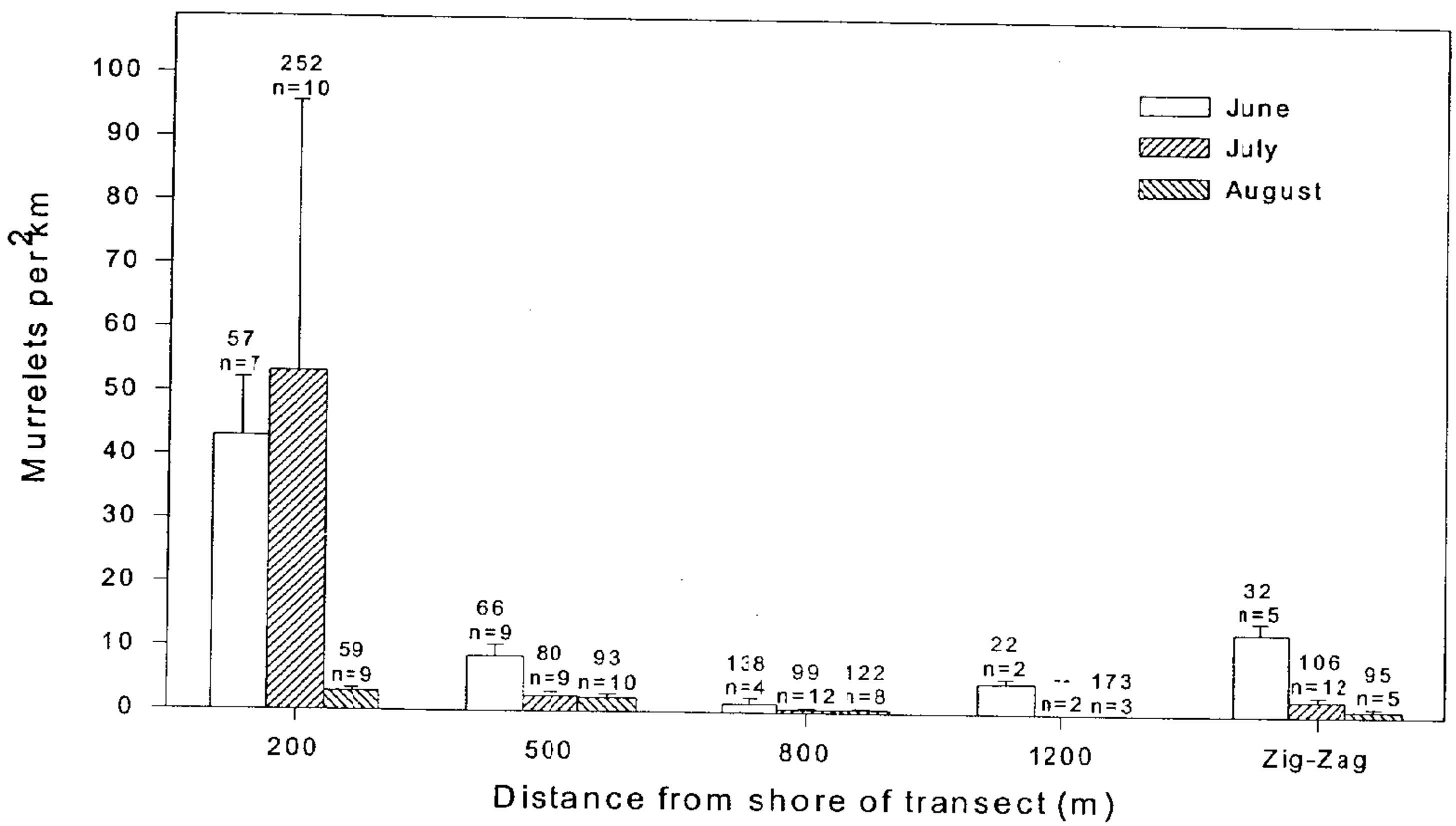

Figure 5. Density of Marbled Murrelets along the western Strait of Juan de Fuca in summer 1995 through summer of 1998 in relation to distance from shore and time of year. Numbers above sample sizes indicate coefficients of variation.

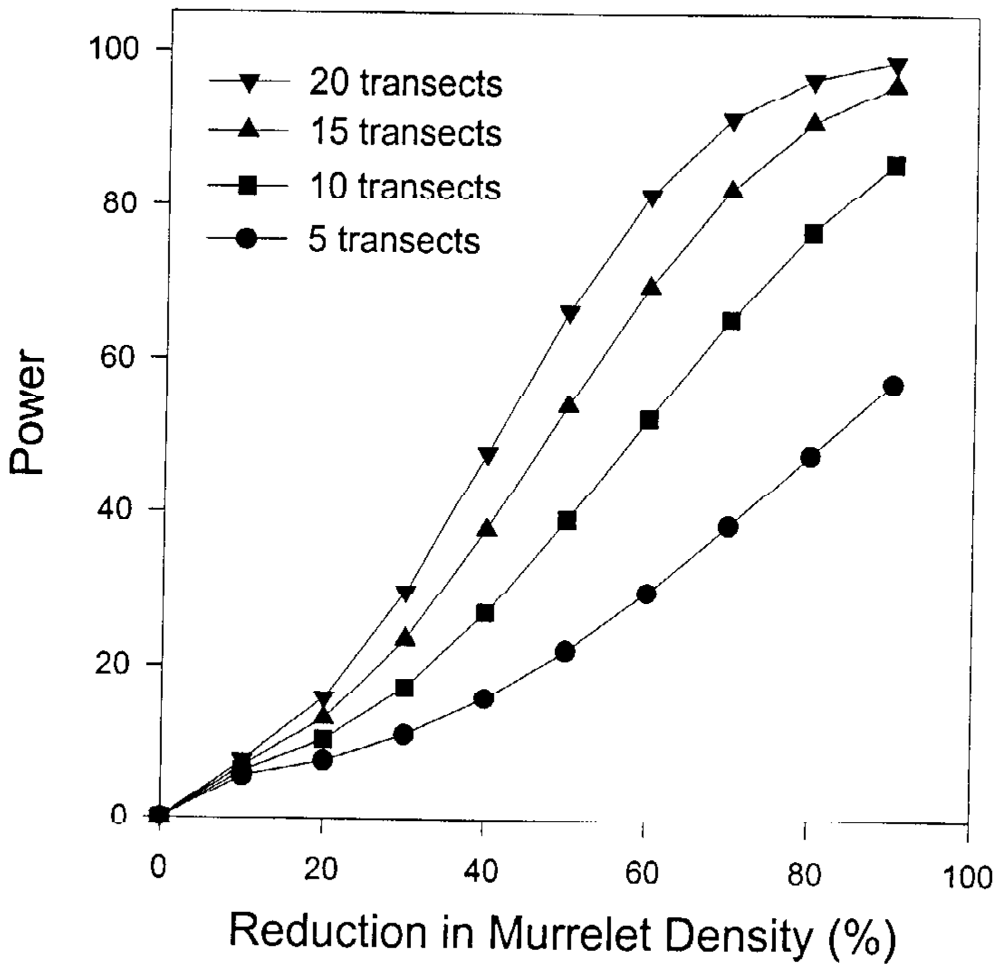

Figure 6. Statistical power of detecting changes in murrelet density along the western Strait of Juan de Fuca by conducting two sets of the same number of transects (5, 10, 15 or 20 replicates) 500 m parallel to shore as a function of the percent change in murrelet density and number of replicates conducted in each set of transects.

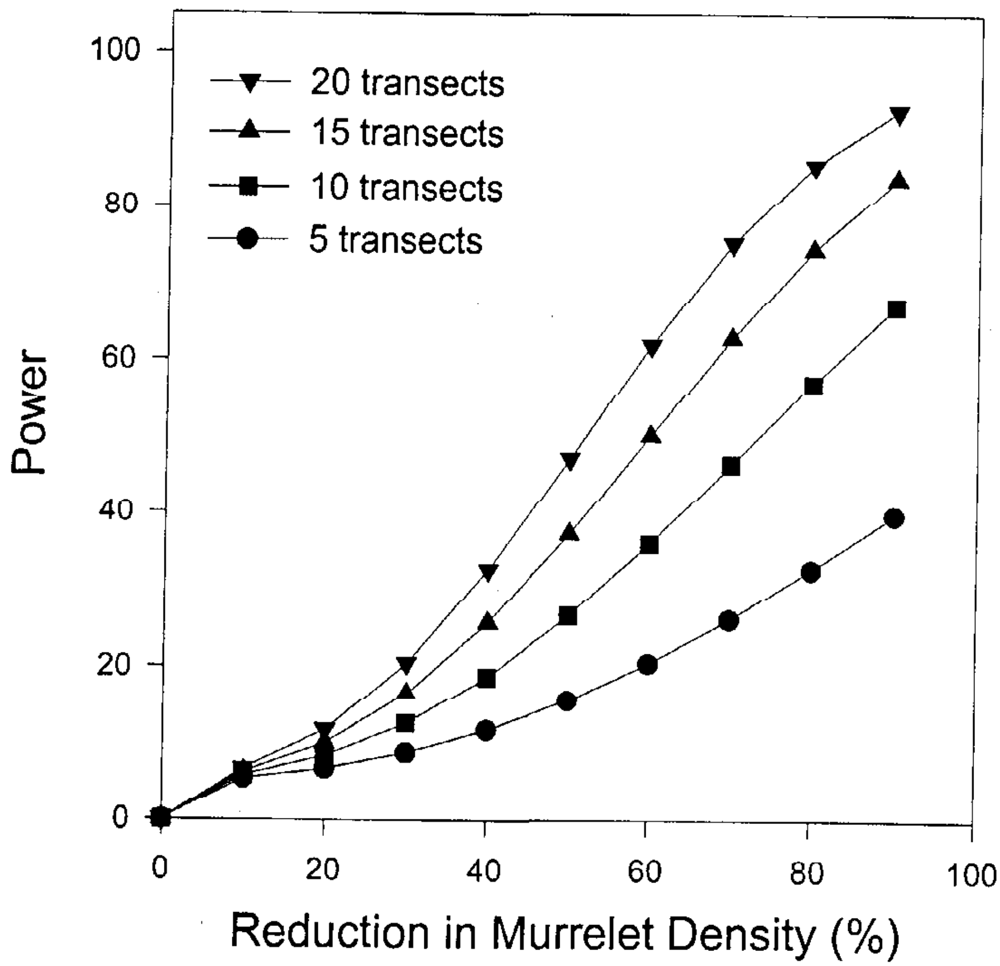

Figure 7. Statistical power of detecting changes in murrelet density along the western Strait of Juan de Fuca by conducting two sets of the same number of zig-zag transects (5, 10, 15 or 20 replicates) as a function of the percent change in murrelet density and number of replicates conducted in each set of transects.

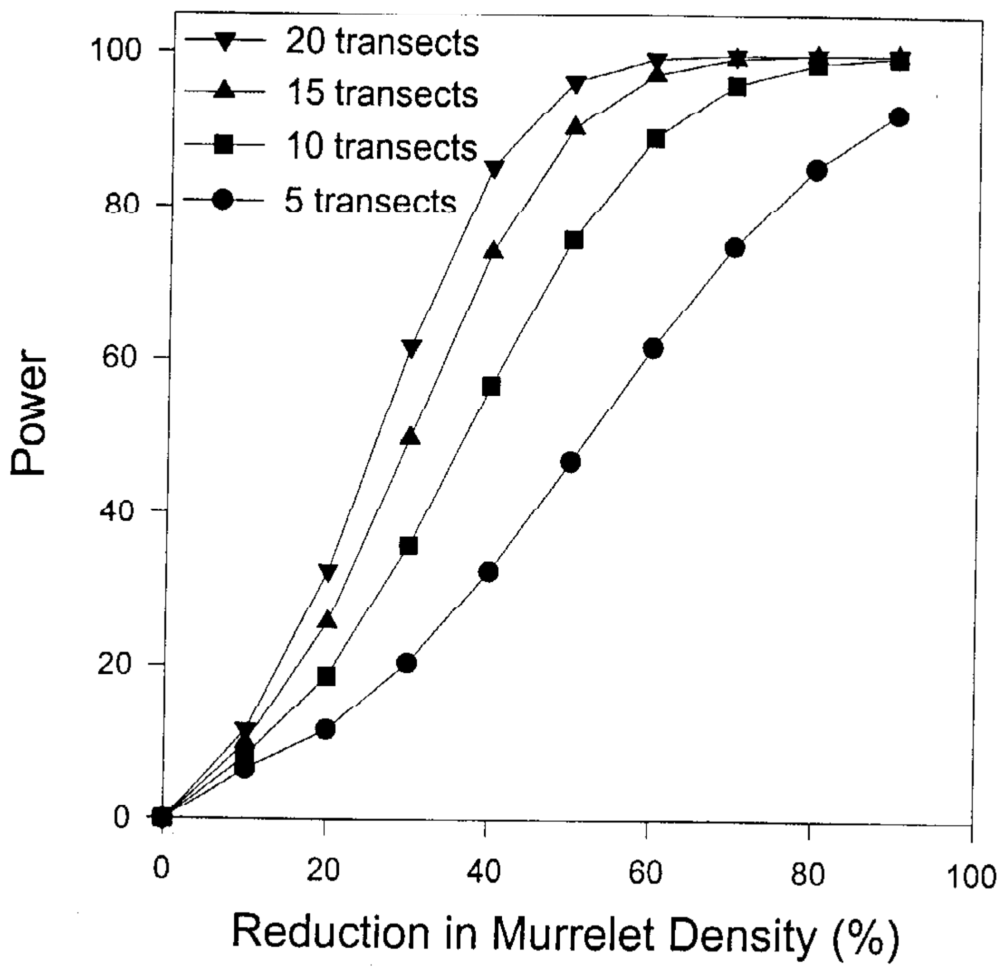

Figure 8. Statistical power of detecting changes in murrelet density along the northern outer coast of Washington by conducting two sets of the same number of transects (5, 10, 15 or 20 replicates) 400 m parallel to shore as a function of the percent change in murrelet density and number of replicates conducted in each set of transects.

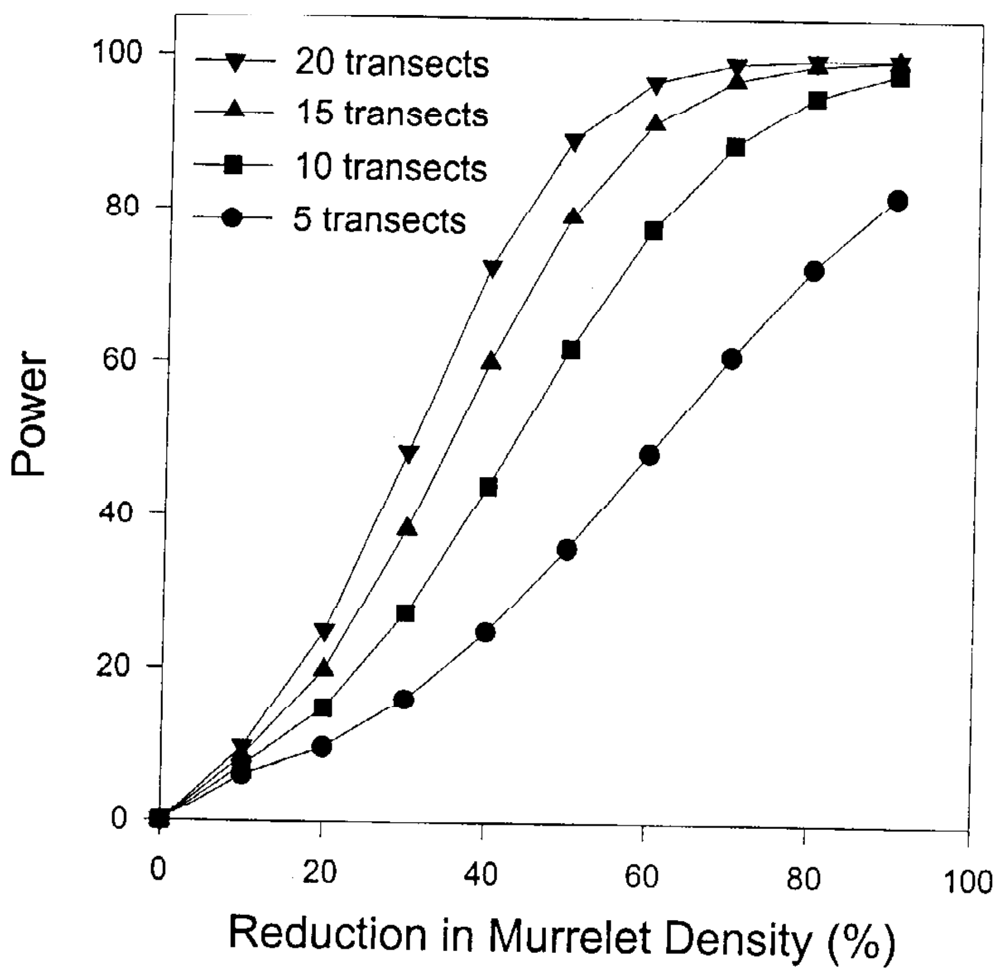

Figure 9. Statistical power of detecting changes in murrelet density along the northern outer coast of Washington by conducting two sets of the same number of zig-zag transects (5, 10, 15 or 20 replicates) as a function of the percent change in murrelet density and number of replicates conducted in each set of transects.

Task 2

We know from past research that numbers of seabirds, including murrelets, are tremendously variable in time and space. This is unfortunate because their inherent variability makes detecting meaningful changes in population levels of these birds very difficult, e.g., in the short-term (within as much as a few years), apparent increases or decreases in population levels may simply reflect variability in numbers of birds breeding, or migrating/dispersing, but not total numbers of birds in a "population." To detect real population changes, these birds must be monitored over many years in order to measure within- and between-year variability in their numbers, and thereby discriminate short-term fluctuations in apparent population numbers from long-term real changes in population numbers. Thus, as indicated in Tables 1-4 (above), since my last report to the TMTC, we have conducted an additional 3374 km of transects in winter and 7680 km of transects in summer. Comparison of mean densities and variances of murres and murrelets from the same transect areas within-season and among years gives us an estimate of interannual variability in murre and murrelet densities within and among geographic areas (Figs. 1-4). Similarly, comparison of mean densities and variances of murres and murrelets from the same transect areas between winter and summer among years gives us an estimate of seasonal variability in murre and murrelet densities within and among geographic areas. Also, comparison of mean densities and variances of murres and murrelets from the same transect areas among months within the same season indicates the extent of within-season variation in their densities. These data and results greatly improve our baseline knowledge of the distribution and abundance of murrelets and other seabirds in Washington.

Task 3

The third task was designed to evaluate transect methodology that could improve our statistical power. In 1995 and 1996 WDFW used "strip" transects for collecting seabird abundance and distribution data; in this method, all birds are counted within a "strip" of 100 meters on each side of our various research vessels. This method has two basic errors: (1) observers must be able to accurate estimate the distance of 100 meters from the vessel in order to accurately determine which birds are inside versus outside the "strip," and (2) the detectability of birds in relation to distance from the vessel differs among transects due to differences in observers, weather (sun, glare, cloud cover, wind, rain), sea conditions (swell height and period, wind waves, etc.), and platform (i.e., vessel height, size, etc.).

An alternative transect method is the "line" transect (Buckland et al. 1993). This method is very similar to the strip transect method, but differs in a few critical ways. In a line transect, like a strip transect, birds are counted only within a specified distance on each side of a vessel; however, in a line transect, the perpendicular distance to each bird from the vessel is also estimated and recorded. By doing so, a detectability curve of the percentage of observations as a function of distance from the boat may be generated. From this, one may empirically determine the percentage of birds being missed on any given transect or set of transects. In turn, this may be used to "correct" transects to reflect the total number of birds that would have been seen if all birds had been detected. By largely eliminating differences in the detectability between transects, this method has the potential to vastly reduce variability in our data, thereby increasing our statistical power. However, the accuracy of this method relies on two critical assumptions being met: (1) all birds must be detected that are "close" (i.e., within about 30 meters) to the transect line of the boat, and (2) the boat must not cause birds to dive, fly or move away from the transect line before being detected. If either of these assumptions are seriously violated, then subsequent analyses of line transect data will yield erroneous results.

During the summer of 1998, we empirically measured (1) the percentage of murrelets on or near the transect line that are not detected, for whatever reason, by standard observers, and (2) the extent to which birds move away from the transect line. We did this by placing an extra "independent" observer on the bow of our vessel who focused most of her effort on or near the transect line. She searched for murrelets well in excess of 100 meters in front of the survey vessel. Once seen, she estimated the angle of the bird off the transect line and its radial distance from the vessel; perpendicular distance of the bird from the transect line is calculated as $X = r*\sin\theta$ where X = perpendicular distance, r = radial distance, and θ = angle from the transect line (Fig. 10). She then followed the bird, noting all behaviors such as flying and diving, and noting

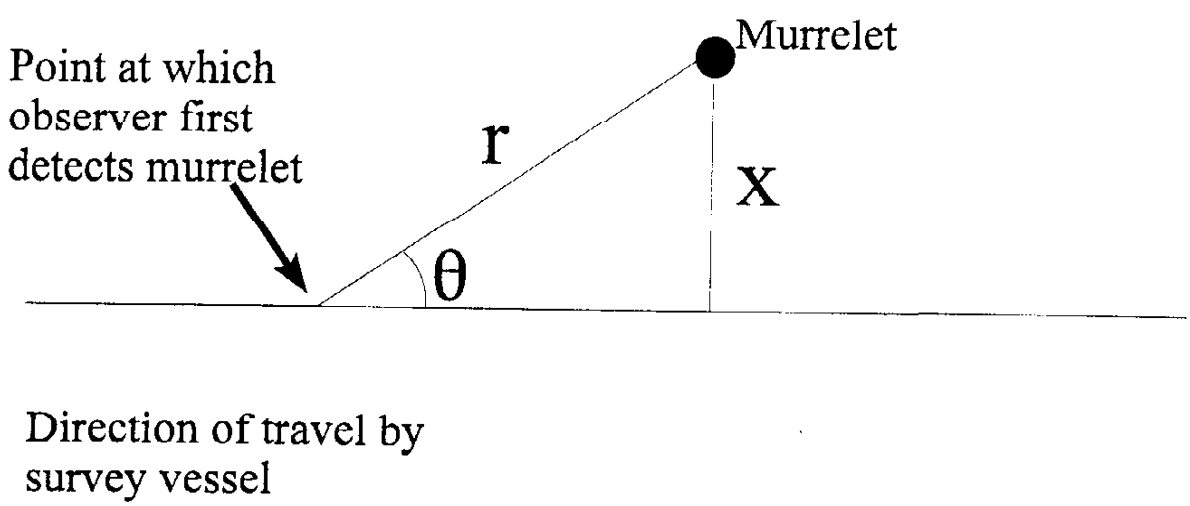

Figure 10. Diagrammatic representation of how line transect observations are made

the position of these behaviors, until it was seen by one of the standard observers. At that time, she took a second set of radial distance and angle estimates. By comparing the perpendicular distance of each murrelet when it was sighted initially by our independent observer to its distance when sighted subsequently by a standard observer, the perpendicular distance that it moved toward or away from the transect line was calculated. If a murrelet was not seen by a standard observer, but was still visible within the transect area (100 radius of the boat), it's position was noted when it was directly abeam of the vessel. If a murrelet was not seen by a standard observer because it dove or flew away, the position at which it dove or flew away was noted by the independent observer.

Results

Percentage of birds not detected by standard observers. This study was designed to allow us to answer a large suite of questions. As a result, the entire data analysis is rather long and complex and are in the process of be prepared as a manuscript for publication (published abstracts of our results will appear in Pacific Seabirds volume 26). However, for the TMTC, we addressed two specific questions: (1) what percentage of murrelets are not detected by standard observers as a function of perpendicular distance from the transect line?, and (2) of murrelets that are detected by standard observers, how far do they move perpendicularly toward or away from the transect line before being detected?

The percentage of murrelets that were not detected by standard observers as a function of perpendicular distance from the transect line is summarized in Table 10 and Figures 11 and 12 below.

Table 10. Percentage of murrelets that were not detected by standard observers as a function of perpendicular distance from the transect line.

Perpendicular Distance (m) from transect line	Birds that dove and were missed	Birds that flew and were missed	Birds that did not fly or dive and were missed	Total birds missed	Total birds not missed	Percent missed from diving	Percent missed from flying	Percent missed that did not fly or dive	Total percent missed	Percent of birds detected
0-10	5	0	3	8	70	6.41	0.00	3.85	10.26	89.74
11-20	9	0	3	12	67	11.39	0.00	3.80	15.19	84.81
21-30	3	0	0	3	48	5.88	0.00	0.00	5.88	94.12
31-40	4	0	2	6	58	6.25	0.00	3.13	9.38	90.63
41-50	1	0	1	2	21	4.35	0.00	4.35	8.70	91.30
51-60	2	0	1	3	19	9.09	0.00	4.55	13.64	86.36
61-70	1	0	3	4	11	6.67	0.00	20.00	26.67	73.33
71-80	0	0	0	0	6	0.00	0.00	0.00	0.00	100.00
81-90	1	0	0	1	3	25.00	0.00	0.00	25.00	75.00
91-100	0	0	0	0	2	0.00	0.00	0.00	0.00	100.00

In collaboration with Tom Hamer (Hamer Environmental, Mt. Vernon, WA), Jeff Laake (National Marine Mammal Lab, NOAA), and Kirsten Brennan (College of Forestry Resources, University of Washington), we used DISTANCE software to estimate the density of murrelets based on the independent observers data (i.e., of murrelets observed presumably before they were disturbed by one of our oncoming survey vessels). We refer to this as the unbiased model meaning that the data are presumably unbiased by any movement by the murrelets caused by disturbance due to our survey vessels. We compared these density estimates to those obtained using the standard observers data (i.e., of murrelets observed presumably after they may have been disturbed by one of our oncoming survey vessels). We refer to this as the biased model meaning that the data may be biased by movement by murrelets away from the transect line in response to oncoming survey vessels. This comparison indicated that densities differed little (10-20%) between these models depending on how parameters were chosen for the DISTANCE software, suggesting that the combination of missed birds and movement of birds does not constitute a large error relative to the magnitude of natural variation in the distribution and abundance of murrelets.

Distance moved toward or away from the transect line by murrelets prior to detection by standard observers. Overall, murrelets do not appear to react strongly to the oncoming approach of survey vessels. Murrelets were initially spotted by the independent observer at 154.4 ± 2.3 m (mean ± SE), and subsequently observed by standard observers at 59.4 ± 1.7 m in front of the vessels. During this interval, murrelets moved, on average, 3.8 ± 1.2 m away from the transect line. However, murrelets closest to the transect line moved away from the transect line a greater absolute distance, and at a greater rate than murrelets further from the transect line (Figures 13 and 14). For example, murrelets within 40m and 20m of the transect line moved 7.3 ± 0.8 m, and 9.7 ± 1.1 m away from the transect line, respectively. We have no explanation for the apparent approach toward the transect line of murrelets initially seen at distances greater than 50 meters perpendicular to the transect line. The most likely explanation is that it reflect a systematic bias in the way the independent observer estimated radial angles and distances of murrelets from the transect line and survey vessel, respectively. However, we tested the independent observer for such biases (Figures 15 and 16), and corrected the raw data to reflect her biases thereby removing most to all bias introduced to the data by her biased data collection.

Discussion

Percentage of birds not detected by standard observers. Overall, these data indicate that 12.7% of murrelets were missed between 0 and 20 meters of the transect line, and 10.7% were missed between 0 and 40 meters of the transect line. As a result, g(0) is significantly less than one, thereby potentially seriously violating one of the basic assumptions of line transect methodology and the DISTANCE software used to analyze such data. The USFWS Population Core group is currently discussing how to deal with this problem. There are two alternatives: (1) ignore the problem and live with the error, or (2) determine and implement a mechanism for estimating a correction factor to reduce the magnitude of the error. The second alternative could be achieved, theoretically, by placing an independent observer on each survey vessel each season for a period of time sufficient to estimate the percentage of birds missed on each vessel. The concern is that this might introduce more error than it corrects for. This was discussed at a meeting of the Population Core Group in mid-May; the consensus was that an independent observer will probably be employed in the summer of 2000 to begin research into the feasibility of using independent observers to estimate percentages of undetected murrelets by various marine murrelet survey crews.

Distance moved away from the transect line by murrelets prior to detection by standard observers. At all distances away from the transect line (e.g., 0-10m, 11-20m, etc.), murrelets moved less than 10 meters away from the transect line, on average, between the time they were were initially spotted by the independent observer and subsequently observed by standard observers. This result is similar to the results of our pilot study in 1997 in which we found that murrelets moved an average of 9.6 ± 1.5m (mean ± SE) away from the transect line (Hamer and Thompson 1997). Calculation of murrelet densities based on data from the biased and unbiased models (described above) indicated that biased data would underestimate unbiased data by about 10-20% depending on values we chose for various parameter inputs into the DISTANCE program (Buckland et al. 1993, Laake et al. 1996) and the perpendicular distance from the transect line at which the data were truncated. Relative to the magnitude of errors introduced into the data from many other sources (e.g. variability among observers and weather conditions such as glare, beaufort magnitude, swell height), it is my opinion, and that of other experts on the subject (e.g., Jeff Laake) that this is not an effect worth trying to control or correct for.

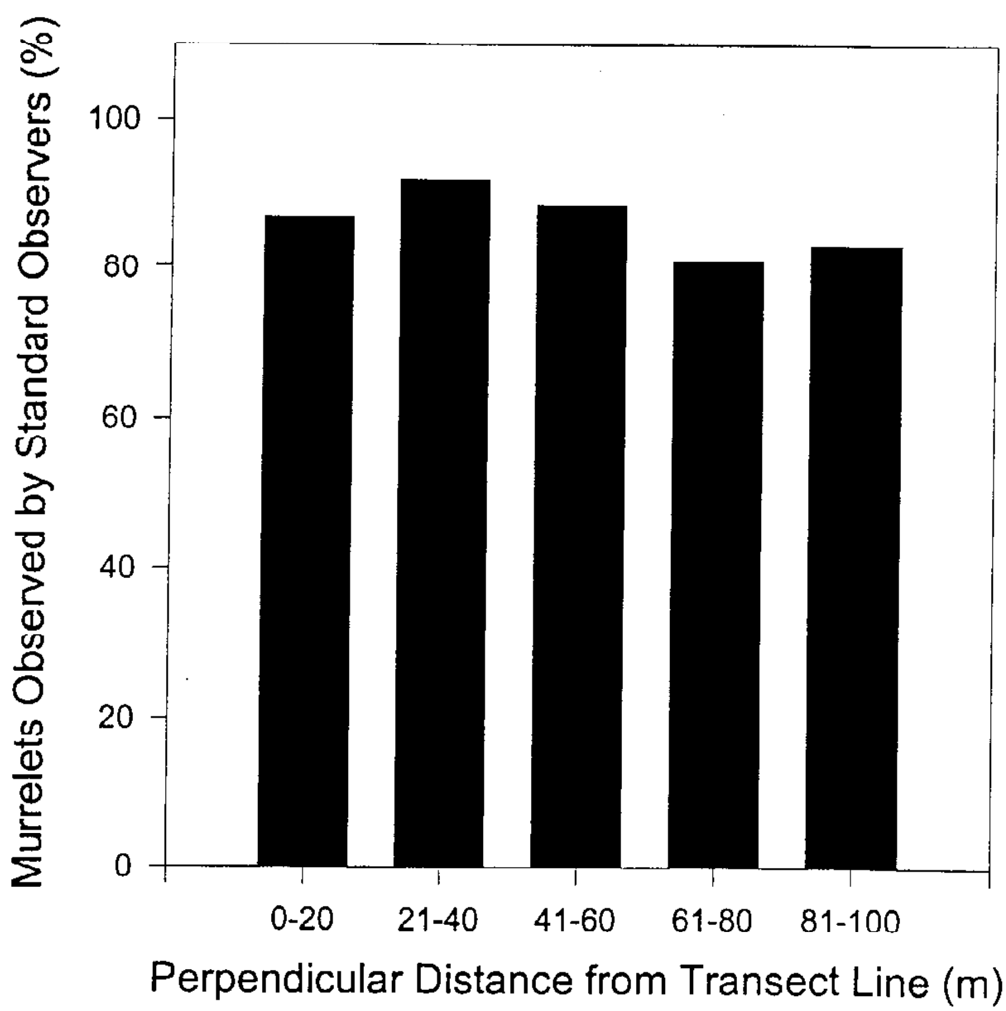

Figure 11. Percentage of murrelets detected by standard observers in relation their perpendicular distance from the transect line.

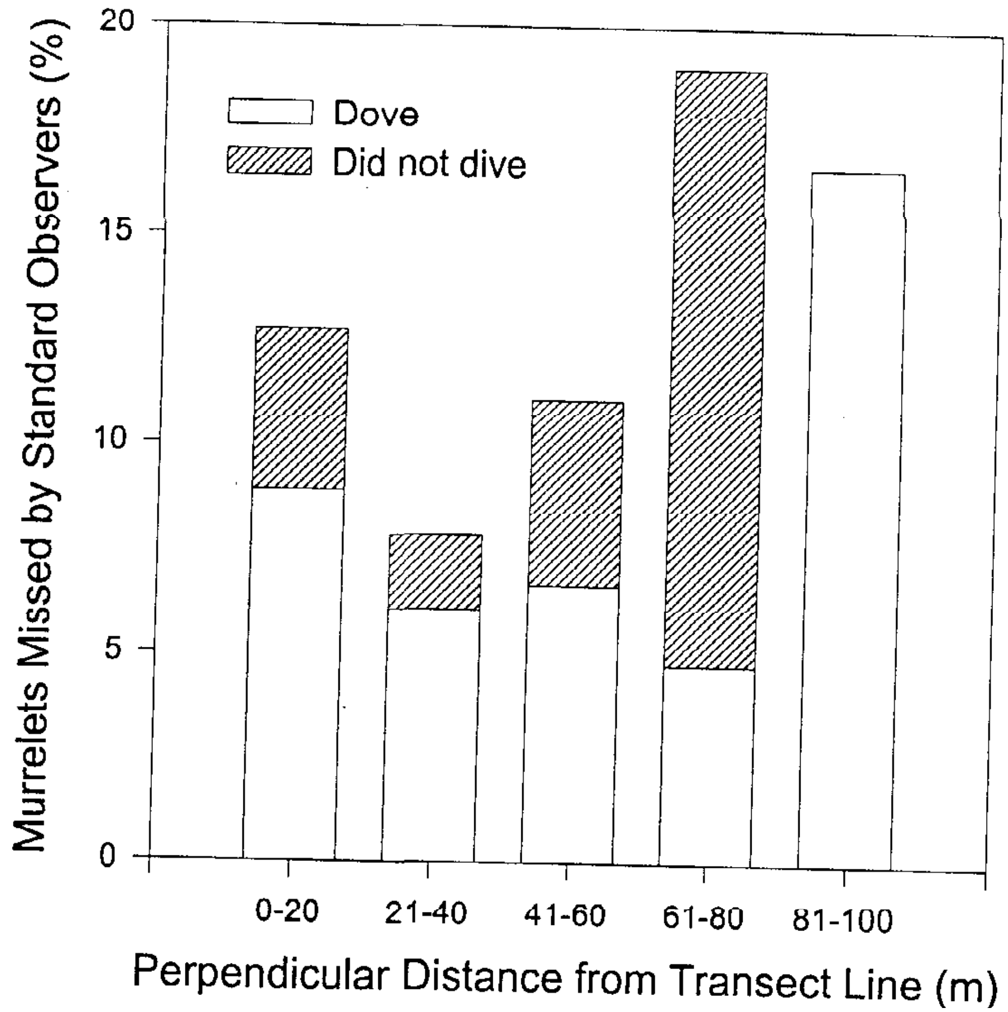

Figure 12. Percentage of murrelets that were not detected by standard observers as a function of murrelet behavior and perpendicular distance from the transect line.

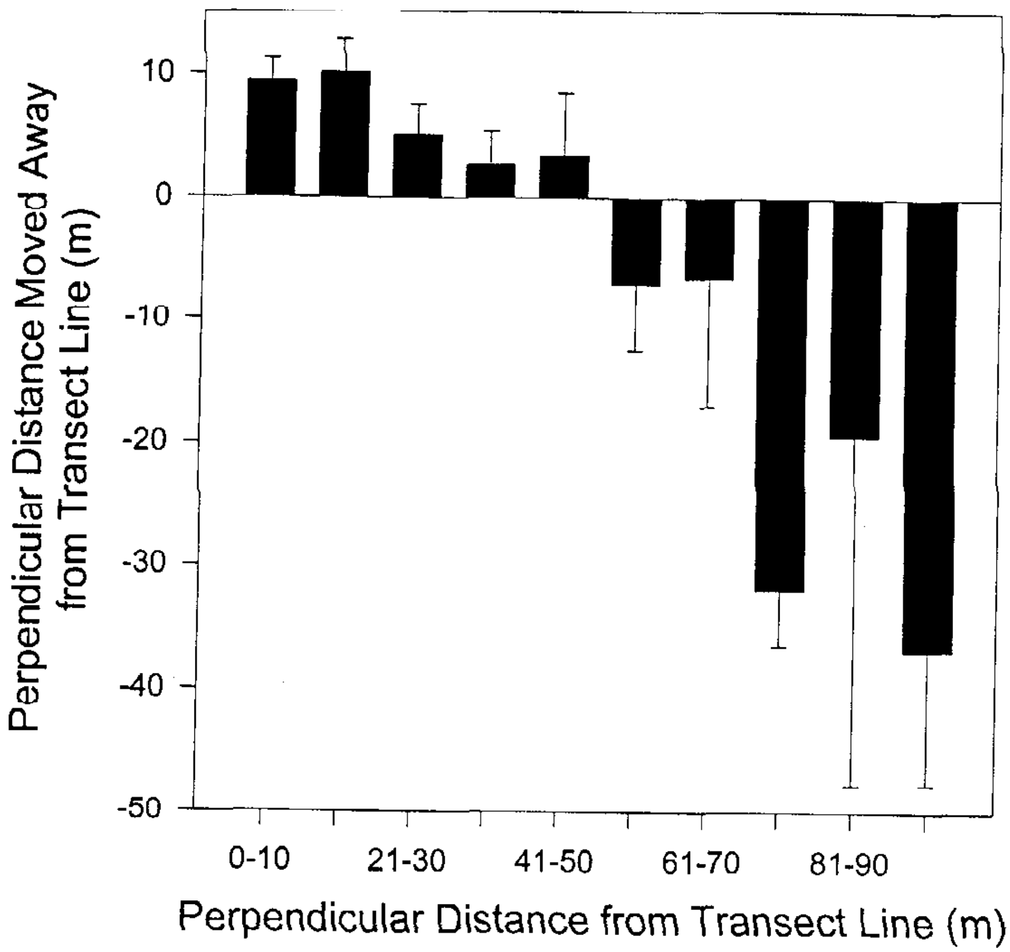

Figure 13. Absolute distance moved perpendicularly away from the transect line by murrelets between their initial sighting by the independent observer and their subsequent sighting by standard observers.

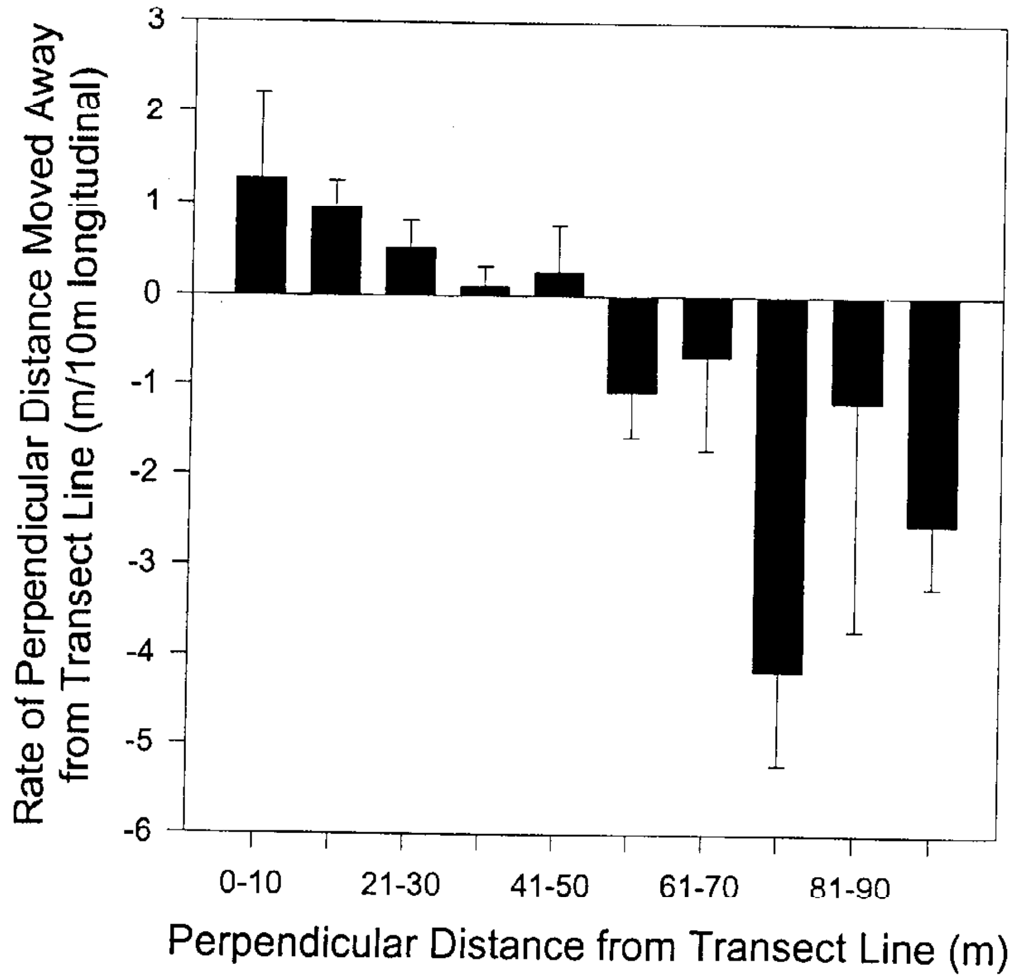

Figure 14. Rate of movement perpendicularly away from the transect line by murrelets between their initial sighting by the independent observer and their subsequent sighting by standard observers.

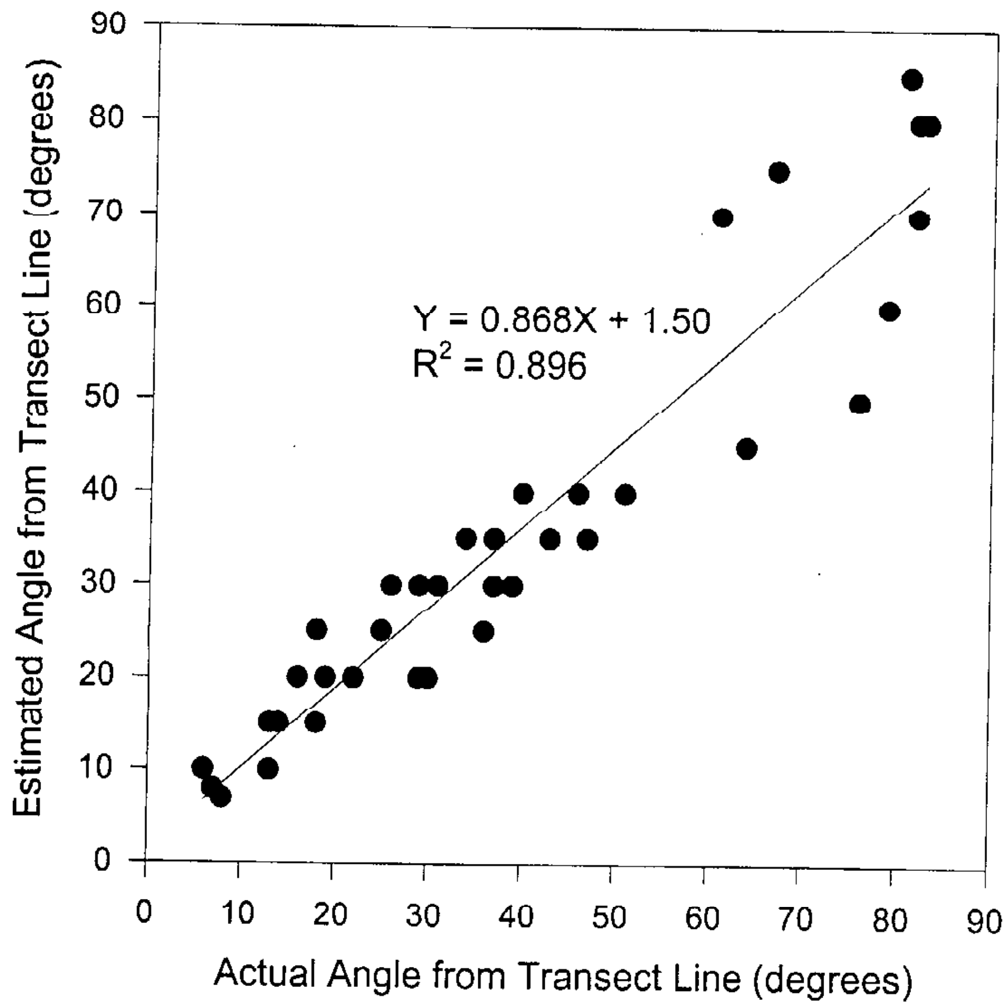

Figure 15. Linear regression of the independent observer's estimated angle from the transect line to buoys (simulating murrelets) on actual angles buoys measured using digital compasses.

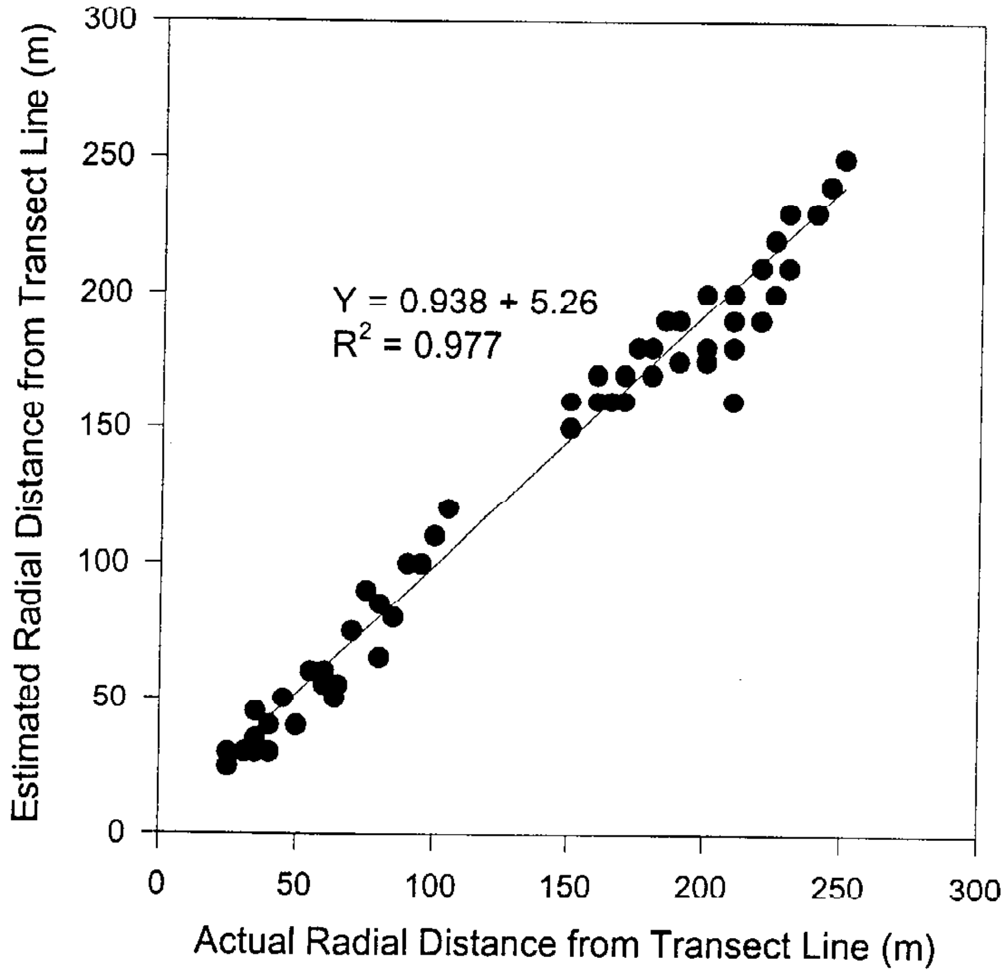

Figure 16. Linear regression of the independent observer's estimated radial distance from the survey vessel to buoys (simulating murrelets) on actual distance to buoys.

Objective 2: Surveys of potential murre breeding colonies.

Historically, murres are known to have bred on many rocks and islands along the outer Washington coast south of Tatoosh Island (Speich and Wahl 1989). However, in the last decade or so, Tatoosh Island is the only colony at which murres are well documented to currently breed annually. Ulrich Wilson (USFWS, unpubl. data) has observed chicks recently on various other colonies (e.g., Huntington Island in mid-June 1995) on which murres are known to have bred previously. These data clearly indicate that murres are breeding in at least small numbers at some other locations in Washington and, in at least some of these colonies, may be doing so earlier than on Tatoosh Island, i.e., the timing of their breeding may be closer to that of Oregon than Washington murre colonies. As a result, better documentation, and estimates of numbers, of breeding pairs of murres at potential Washington Murre colonies other than Tatoosh Island are necessary. In addition, individual murre breeding colonies vary tremendously in their phenology as well as their relative attendance and reproductive success. This variation presumably reflects both local and regional differences among colonies, especially with regard to prey availability. With regard to the breeding of murres at colonies in Washington other than Tatoosh Island, it is unclear whether they tend to more closely follow the phenology of Oregon or Washington colonies (i.e. Tatoosh Island). As a result, the objective of this study was to complete two specific tasks:

(1) Conduct land-based surveys of the Grenville complex (Erin, Erin's Bride, Grenville Arch and Big Stack) for possible breeding activity.
(2) If murres are breeding at the Grenville complex, determine whether their breeding phenology is closer to that of Oregon colonies versus Tatoosh Island for the same season.

Tasks 1 and 2

Every one to seven days between 10 July - 7 August, 1997, and 2 July - 29 July 1998, we used a Questar telescope to observe the Grenville complex from the old naval base on the Quinault Indian Nation for potential murre attendance and breeding activity (Table 11). The structure of the Grenville Complex rocks is such that very little of the suitable habitat available to murres is visible from this observation point; most of the available nesting area is on the west side of these rocks that is not visible from the old naval base. As a result, aerial surveys conducted by Ulrich Wilson (USFWS) and others (e.g. Steve Jeffries, WDFW) have yielded counts in the thousands in recent years. However, the main objective of this study was not to obtain absolute numbers of murres attending and/or breeding on these rocks, but rather to determine whether they were attempting to breed and successfully rearing young. Although it is rarely possible to identify chicks from airplanes during aerial surveys, land-based observations are clearly superior for monitoring potential reproductive activity.

In general, attendance was lowest early in the morning and greatest at the end of the day; attendance typically increased to an initial maximum by 1030 h, subsequently decreased until 1230 h, and then increased again to a daily maximum at about 1730 h. As indicated in Table 11, eggs were first observed in early July and last seen on 5 August; in addition, chicks were first